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Energy, environment and development in Bhutan

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Abstract

Bhutan's energy and environmental situation and approaches to development are reviewed and analyzed in this paper. *Conservation* of natural resources and *human happiness* have been placed as central strategic policy themes and have been given high priority in the national development plans of Bhutan. Bhutan's unique approach to development via *Gross National Happiness* (*GNH*) or *the Middle Path* of development is being facilitated by the Royal Government of Bhutan as a tool to balance poverty alleviation, environmental conservation and development. However, challenges exist due to the constraints of resources, good governance, legal frameworks, and human capacity. This paper reviews selected sustainable energy projects (e.g. energy from renewables or energy conservation) in Bhutan and finds that in fact, Bhutan's renewable energy resources (e.g. water and forests) which have proved to be indispensable for development are vulnerable due to the adverse impacts of climate change and environmental degradation. Appropriate measures in order to reduce potential environmental degradation and mitigate climate change impacts have been acknowledged globally and these have potential for application in Bhutan. For example, implementation of sustainable energy projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol could offer an opportunity for mitigating climate change impacts and also contributing to sustainable development.

Keywords: Bhutan; Sustainable development; Gross National Happiness; Renewables; Hydropower

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Contents

1. Introduction

Bhutan is no longer an isolated economy. Over the past 40 years of planned development, Bhutan has had significant interaction with the rest of the world with regard to development opportunities. This has meant that Bhutan, like other nations has also been subjected to the environmental impacts from development. The Royal Government of Bhutan's (RGB) approach towards development via *Gross National Happiness (GNH)* or *the Middle Path* of development has been implemented to appropriately balance the pressures of society, economy, politics, culture and the environment.

This approach acknowledges that access to affordable energy services and protection of the environment are indispensable for development. Both fossil fuel and renewable resources have been used in Bhutan for energy services, but energy services from fossil fuel resources have had environmental consequences throughout the entire fuel life cycle. Also provision and use of fossil fuels for energy services is a major concern in Bhutan due to its disparity of geographic and geophysical settings and variable availability of energy resources. In contrast, energy services from renewable resources, both water and forest based in a sustainable manner have been harnessed with minimal or zero environmental and social consequences. Also *on-site* development of energy services from renewable resources has exhibited synergistic benefits such as reduction of poverty, energy security

and economic development. However, challenges exist for Bhutan in terms of availability of resources, legal frameworks, governance and human capacity to further harness adequate and affordable energy services from renewable resources in a sustainable way.

This paper reviews energy and development approaches in Bhutan. The first part of the paper starts with describing the geophysical setting of Bhutan; this is followed by reviewing the socio-economic context, development trends, and national development planning. Then the outlook on energy and environment is discussed together with observations about institutional settings and approaches to addressing environmental protection and climate change. The final part of the paper analyzes sustainable energy demonstration projects and discusses challenges and future opportunities.

2. Background

2.1. Geophysical setting of Bhutan

Bhutan, a landlocked country, and is located within the Eastern Himalayas, is one of the world's 10 global biodiversity *hot spots*, with a land area of about 47,000 km^2 [1]. Bhutan is bordered by the Tibetan Autonomous Region of China on the north and by India on the west, south and east (see Fig. 1 for location of Bhutan). Virtually all of Bhutan is mountainous and the terrain is highly rugged with an elevation of 100 m above sea level in the south to over 7500 m in the north. Three major landform features are evident in Bhutan: the southern foothills comprising steep hills and dense forests; the inner Himalayas, with broad river valleys; and the high Himalayas, featuring snow capped mountains. The climatic conditions also vary in Bhutan and the three landforms have distinctive climates. Heat and humidity characterize the southern foothills, which have an annual rainfall of 2500–5000 mm; in contrast, the inner Himalayas have a cool, temperate climate, with an annual rainfall of 1000 mm; the high Himalayas feature a severe alpine climate and annual rainfall of only 400 mm [2]. About three-quarters of the land area in Bhutan is covered by forests of temperate and sub-tropical species [3].

2.2. Socio-economic context of Bhutan

Bhutan is the least-populated country in South Asia[1] with 873,700 people and the population growth rate was 3% in 2003 which was higher than the world average of 1.27% [1]. Bhutan is one of the world's least-urbanized countries, with only 21% of the total population living in the urban areas [4]. However, it is expected that close to half of the population will reside in urban centers by 2020 if the current trends of rural-urban migration continue [5]. The majority of the people currently live in the nation's valleys at an altitude of 1000–3000 m [6]. Table 1 provides socio-economic indicators for Bhutan.

Modernization of Bhutan's economy began in the early 1960s with the establishment of basic infrastructure such as: roads, power, telecommunications, and transport [7]. Followed its early modernization, Bhutan's economy has exhibited robust growth with

[1]South Asia comprises Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka (Afghanistan is yet be a full-member of the South Asian Association for Regional Cooperation (SAARC); and China and Japan are yet to act as Observers, Dhaka declaration, November 2005, via http://www.saarc-sec.org/ accessed on January 18, 2006).



Fig. 1. Location of Kingdom of Bhutan. *Source*: Adapted from Kezang and Whalley, 2004.

Table 1
Socio-economic indicators of Bhutan

Capital of Kingdom of Bhutan	Thimphu
Land area (km^2)	47,000
Forest cover (%)	72.5
Arable land area (%)	7.5
Population (2002)	873,700
Urban population (%)	21
Population growth rate (%) (2002)	3
Total GDP (US$ million) (2002)	603
Per capita GDP (US$) (2002)	700
Government	Monarchy
Religion	Buddhism
Major industries	Mining, timber, fruits, tourism, hydropower
Major trading partners	India, Bangladesh

Source: Adapted from WB, 2005.

the move from a non-monetized traditional economy based on agriculture to a modern wage-based exchange economy since 1981 [4]. However, agriculture is still critical to the Bhutanese economy. About 79% of the population depends on agriculture for their livelihood and it accounted for about 33% of GDP in 2002 (16.2% from agriculture; 7% from livestock; and 9.8% from forestry) [8]. Among the share of other modern sectors

(comprised of manufacturing, mining, electricity and construction), electricity from hydropower accounted for 12% of GDP in 2003 [5] and is expected to be 14.6% by the end of Bhutan's 9th Five-Year Plan in 2007 [3]. Electricity from hydropower provided about 45% of national revenue during 2000–01 and is increasingly fundamental to the country's economic development [7].

Average per capita GDP was US$590 per annum in 2002, which is higher in comparison with the South Asian average of US$460 per annum [8]. However, there is still considerable poverty in Bhutan. About 31% of the total population live below the poverty line[2] of US$200 per annum according to the National Statistical Bureau of the RGB [9]. The associated urban and rural poverty levels are estimated to about 4.2% and 38.3%, respectively [5]. However, strong macroeconomic performance has underpinned poverty reduction efforts in Bhutan. Economic growth accelerated from 5.5% in the first half of the 1990s to over 7% during 1999–2004 [5]. The Government's social welfare policies, including free medical care, have resulted in relatively high levels of human development[3] and also relatively widespread social well being, particularly in Thimphu, the capital city of Bhutan [4].

2.3. Development trends and planning

Poverty alleviation and improved well being are two common and overarching development goals for most South Asian nations including Bhutan. However, indicators, means, and strategies for achieving these objectives differ considerably for each individual nation. After centuries of self-imposed isolation, Bhutan opened its borders to the outside world in the early 1960s, during the reign of King Jigme Dorji Wangchuck and this drove forces of change towards modernization [3,10]. Historically, the development process in Bhutan was first initiated in 1961 via the 1st Five-Year Plan and Bhutan has to date successfully completed four decades of planned development via eight Five-Year Development Plans [11].

Bhutan's philosophy of development was clearly enunciated by His Majesty King Jigme Singye Wangchuck as the *Maximization of GNH* in the late 1980s [11]. Similar development approaches such as *downshifting* [12] and *sufficiency economy* have been proposed theoretically in the context of Australia, and in planning and policy in Thailand [13], respectively. However, policy formulation and implementation has not been realised for Australia and effectiveness is yet to be confirmed for Thailand. GNH stresses differences between the concepts of wealth and prosperity, and highlights higher standards of living through moderate lifestyles [2]. The unique concept of GNH has many more dimensions than those associated with GDP and this calls for a multi-dimensional approach towards development in a sustainable way that seeks to maintain harmony, maximize happiness and balance economic forces, environmental preservation, cultural and spiritual values, and good governance with less dependence on global finite resources [9,14].

[2]The poverty line is the level of income below which one cannot afford to purchase all the resources on requires living. The global standard of poverty line is US$1 per day (including self-produced goods and services). However, in practice, different countries often use different poverty lines.

[3]The United Nations Human Development Index (HDI) is a comparative measure of poverty, literacy, education, life expectancy and other factors for countries worldwide. Bhutan's HDI ranked 136 (0.511 in 2003).

In the context of Bhutan, there are a number of conditions conducive to the development of GNH. These include: geographic setting as discussed earlier, size of the economy, the influence of Buddhism on the national culture, and support from the King and the Government [15]. While Buddhism as a path of self transformation has to be taken on consciously by each individual concerned, historically it has played a significant role in developing conditions that have had a very positive impact on local culture and society. GNH is rooted in the Buddhist philosophy and religion, which interprets nature as a living system rather than just a resource base to be exploited for material gain. In fact, the expression of GNH in Bhutan is essentially a summarization of the basic tenents of *Vajrayana Buddhism*, which encourages a culture of harmony and compassion. GNH also bridges the gap between values and development [16]. Therefore, the ideals of GNH place Bhutan on a footing, where it can exercise options and obtain judicious benefits from the process of liberalization and globalization taking environmental, social and cultural impacts into account. It is seen as the overarching philosophical underpinning and the ultimate guideline for the nation's future [16].

However, having accepted that maximization of GNH is a philosophy for development since the 1980s [3], the Bhutanese Government has identified four areas as the main pillars for development namely: economic growth and development; preservation and promotion of cultural heritage; preservation and sustainable use of the environment; and good governance [3]. These main pillars, however, do not limit other areas, which could contribute towards furthering Bhutan's development philosophy and objectives.

While the nation's future development strategy released in 1999, 'Bhutan 2020: A Vision for Peace, Prosperity and Happiness', contains long-term visions, directives for future commitments and distinctive guidelines for the nation's development, short- to medium-term planning is outlined in the national Five-Year Plans [3]. The five thematic areas in the strategy, under which are set powerful objectives for steering the process of change, include: human development, culture and heritage, balanced and equitable development, governance, and environmental conservation [11]. These five themes not only make the concept of GNH more tangible, but also embody a guiding principle that has been identified by the Government as being of decisive importance in ensuring future independence—ensuring sovereignty and security of the nation [7].

Taking into account, the trends of development during previous Five-Year Plans, the 9th Five-Year Plan (2002–2007) set the following goals: improving quality of life and income, especially of the poor; ensuring good governance; promoting private sector growth and employment generation; preserving and promoting cultural heritage and environmental conservation; and achieving rapid economic growth and transformation [3]. In order to achieve these objectives, the Government's strategic priorities included: expanding infrastructure; setting sound macroeconomic policy; ensuring good governance; and improving access and enhancing social services [5]. However, the 9th Five-Year Plan differs from past plans in way that it includes individual plans for the 20 *Dzongkhag*[4] (districts) and 201 *Geogs*[5] (blocks) prepared by their communities and their elected representatives [5]. The process of decentralization of central Government to the districts and blocks in Bhutan has been designed to emphasize the need for the population to be

[4]D*zongkhag* or districts.
[5]*Geogs* or blocks (lowest administrative unit).

self-reliant and take greater responsibility for required infrastructure and services and also to decentralize public expenditure responsibilities [5].

3. Overview of the energy situation and the environment

3.1. Energy resources

Bhutan has no significant reserves of fossil energy resources (oil, natural gas or petroleum products) except for limited coal reserves in the southeastern part of the nation [17]. These reserves are estimated to be about 2 Mt of low-grade coal, which is unsuitable for industrial purposes [18]. Accordingly, all petroleum products (kerosene, diesel, petrol and liquefied propane gas, aviation turbine fuel) are imported for the purposes of lighting, transportation, cooking and heating. For example, imports of fossil fuels during 1999–2000 included 26.8 Ml of diesel; 6.5 Ml of petrol, 15 Ml of kerosene, 3000 t of LPG and 890 kl of aviation turbine oil [19,20]. Bhutan is endowed with rich water and forest resources that can be used substantially for energy purposes. In Bhutan, electricity-generating capacity from hydropower was 468 MW in 2004 [21]. Also about 13 MW of electricity is generated from diesel generators [22].

Bhutan's water resources for hydropower and forest resources for fuel wood are discussed below separately followed by an overview of other renewables used to date.

3.1.1. Hydropower

Bhutan is drained by four major river systems (the Ammochu, the Wangchu, the Sankosh, and the Mansa) with their estimated total length being about 7200 km [23]. The swift flow of water from densely covered forest catchment areas provides abundant potential for hydropower and has varying drops of head from 7000 to 100 m. Thus Bhutan is endowed with rich potential for harnessing hydropower from *run-of-the-river*[6] plants. According to the Austrian Development Cooperation (ADC), the estimated potential for hydropower in Bhutan is over 30,000 MW [24]. A Power System Master Plan Study (1990–93) conducted with technical assistance from the United Nations Development Program (UNDP) and the Norwegian Development Cooperation Agency (NORAD) identified 91 potential hydropower sites with above 10 MW of capacity [24,25]. An update and revised Power System Master Plan (2002–03) conducted under the technical assistance of NORAD and taking into account the sustainable use of water resources, showed a feasible capacity for exploitation of more than 23,000 MW of hydropower [24]. However, exploitation of hydropower by the end of 9th Five-Year Plan in 2007 is estimated at about 1490 MW of installed capacity (including hydropower projects at Tala 1020 MW, Kurichu 60 MW, and Bashochhu 64 MW) and 2800 MW under feasibility study (including potential hydropower schemes at Mangdechu 380 MW, Wnagchu 900 MW, and Bunakha 180 MW) [24,26,27].

3.1.2. Fuel wood

Bhutan's total forest area is estimated to 2.9 million ha which accounts for 72.5% of the total land area of the nation [28,29]. The use of forest resources is an essential component of Bhutanese livelihood and is intricately woven into the

[6] A run-of-the-river plant relies on the flow of the river to spin the water turbine.

national culture. For example, forests are used as a source for fuel wood and for non-wood forest products. Non-wood forest products include medicinal plants, resin, natural dyes, bamboo etc. These contribute significantly to the livelihood and food security of Bhutan's rural households. Most of these products are directly consumed and so do not enter the formal monetary economy. For this reason, their importance is often overlooked.

Fuel wood accounts for over three-quarters of total energy consumption in Bhutan and virtually all non-commercial energy consumption, of which the household sector accounts for 95% followed by the Government and commercial sectors' consumption (3%), and the agricultural and industrial sectors' consumption (1%), [17,24,27]. According to the wood energy sectoral analysis published by the Food and Agriculture Organization (FAO) of the United Nations in 1991, Bhutanese people consume over 1.27 t of fuel wood per capita per year, ranking the highest in the world[7] [19,30]. However, the consumption patterns for fuel wood vary in urban and rural areas depending on availability of forest resources and alternatives. While fuel wood consumption in urban areas has changed since the early 1990s due to the availability of modern cooking and heating appliances (e.g. gas stoves, oil radiator heaters etc.) and changing lifestyles, fuel wood consumption in rural areas remains the same due to a lack of suitable alternatives and socio-economic constraints [19].

Except for urban and semi-urban centers, most of the fuel wood consumed in the domestic sector as well as non-domestic sectors originates from Government owned forests, and the rest comes from privately owned land [17]. Government owned forests provide wood at no charge to users. Commercial fuel wood users also rely largely on public forests as a free resource [24].

3.1.3. Other renewables

There is also potential for other renewables in Bhutan. These include: mini/micro hydropower (<1 MW); solar photovoltaic (PV); biogas; and wind power for electricity generation in rural and isolated areas of Bhutan. About 23 micro/mini-hydropower plants have been installed in Bhutan with a total capacity of 5 MW installed by 1999 [31]. Also, a baseline study on mini/micro hydropower during 1999 facilitated by the Global Environmental Facility (GEF) recommended a further four sites in Bhutan for implementation of mini/micro hydropower schemes, where grid connections were likely to remain elusive over the next 10–15 years [32].[8] Also with good sunshine hours, solar PV systems are proving a viable alternative and are cost-effective compared to grid electricity transmissions, especially in remote and isolated areas in Bhutan. The first solar PV program was launched in Bhutan during the early 1980s. By the end of 1997, there were 1316 solar PV panels installed and these were providing electricity for several communities and other basic service units [3,26]. Biogas is used to a limited extent for lighting and cooking and is primarily generated from cow dung. The potential for wind power generated electricity is yet to be determined.

[7]This analysis was a part of the Master Plan for Forestry Development project and is the only comprehensive wood energy study carried out in Bhutan to date (Norbu and Giri, 2004).

[8]Latest available data.

3.2. Energy consumption patterns

Bhutan's overall electricity demand was 105 MW (664 GWh) in 2003 and 99.5% of electricity was supplied from hydropower schemes [21]; while per capita electricity consumption in Bhutan for that year was 949 kWh [21] which was a 50% increase compared with 1997–1998 (610 kWh) [26]. Electricity is consumed by domestic, commercial and industrial users with industry using the lowest share. The demand for electricity consumption in the domestic sector has increased substantially in recent years. For instance, annual domestic electricity consumption in Bhutan increased by over 9% during 1995–2000 and total electricity demand increased from 70 MW in 1995 to over 90 MW in 2000 [20]. Commercial energy consumption in Bhutan is dominated by electricity from hydropower which accounts for about 80% of commercial demand followed by petroleum (13%) predominantly used for transport, and coal (7%) [33]. The growth in electricity consumption in the industrial sector increased from 76.5% (110 M kWh) in 1990–91 to 84% (317 M kWh) in 1998–99 [26].

Access to electricity is limited in rural Bhutan due to lack of an electricity grid network throughout the rural areas of the nation. Only approximately 40% of the total population and about 30% of the rural population in Bhutan (in 40 towns and 822 villages) have access to electricity [21]. However, there is a positive correlation between rural electrification and environmental conservation, since houses that are electrified via electricity from hydropower schemes tend to use less fuel wood and kerosene (and the run-of-the-river hydropower schemes are of low environmental and social impact in comparison with some types of hydropower scheme). A recent evaluation has shown that electrification reduces fuel wood consumption by 25–35% [24]. It is expected that during the 9th Five-Year Plan, around an additional 15,000 households will be connected to the electricity grid [3,24]. Also, following the trends of electrification, 100% rural electrification is projected by 2020 for Bhutan [3,24]. Although rural hydropower electrification is gaining ground and many rural homes also are now installing solar PV systems these are largely limited to lighting purposes whereas energy use in rural areas is most intensively used for cooking and space heating purposes especially at high altitudes [19]. This means that fuel wood will continue as an important energy source in rural areas for many years to come.

3.3. Energy-related environmental impacts

Competition for land, forest and water resources has increased as economic development has proceeded in Bhutan [5]. Thus concerns about the environmental impacts from development have been given high consideration during planning especially with regard to the development of energy generation schemes in Bhutan. Despite Bhutan's high dependence on hydropower for electricity and its forest resources being carbon sinks, Bhutan's energy dependent sectors cause several environmental impacts.

Electricity from hydropower minimizes both emissions of greenhouse gases and health hazards associated with combustion of fuel wood. Per-capita annual emissions of CO_2 in Bhutan were only around 0.5 t in 1998. This is of low significance compared to the world average of 3.8 t in 2003 [34]. Also most of Bhutan's hydropower schemes (both already built and proposed) are mainly run-of-the-river schemes with no impact or minimal impact to the environment [21]. In fact, hydropower schemes are argued to have positive impacts

on Bhutanese society due to spin-off effects[9] [21]. However, the energy-dependent sectors (road transport, residential/commercial, manufacturing, and construction) contributed about 95 Kt of CO_2 emissions in 1994 [28]. Among others, the transport sector contributed 45.3% of emissions of CO_2, followed by the combined residential/commercial sectors (28.7%); manufacturing industries (17.1%); and energy conversion (8.9%) [28]. Although, land use change and forestry activities emitted a significant amount of CO_2 they resulted in a net CO_2 removal of 3.5 Mt because of strong uptake of CO_2 through forestry management and plantations as well as reforestation via abandonment of managed agricultural land [28].

It has been acknowledged that the most damaging impacts of climate change in Bhutan will be on water resources associated with glacier lake outbursts [35]. There are numerous snow-clad mountains and glacial lakes in the northern region of Bhutan. An increase in global surface temperature due to the greenhouse effect will result in the retreat of glaciers, increase of the volume of glacial lakes and ultimately will provoke glacial lake outburst floods (GLOFs) with potentially catastrophic consequences, especially on hydropower schemes. According to a report published by the International Center of Integrated Mountain Development (ICIMOD) and UNEP, 24 out of 2,674 glacial lakes in Bhutan are potentially dangerous [36]. The 1994 flash flood on the Pho Chhu River following a glacial lake outburst in the Lunana area was one such example [35]. However, after several forays in the area by experts there is still no hope for a permanent solution and the Government is making attempts to reduce risks [36]. One possible severe threat from glacial lake outbursts to the further development of hydropower schemes is the potential for increasing sediment loads in Bhutan's extensive river systems [37].

Burning of fuel wood in Bhutanese households causes significant indoor air pollution including severe health impacts. Also due to the growing outdoor air pollution from vehicle and industry emissions in Bhutan, there is an upward trend in the incidence of health-related environmental impacts. For example, acute respiratory disease attributed to air pollution increased form 10% of the total population in 1990 to 14% in 1998 [26]. Similar upward trends also have been observed for other respiratory diseases such as coughs and colds, bronchitis, and asthma [26].

Deforestation also has been a result of over-exploitation of fuel wood from Government or private forests [19]. Some of the forest areas are also now subject to unsustainable harvesting of fuel wood due to increasing demands for fuel wood by larger settlements around the forests [29,31].

4. Energy policy and institutions

Electricity is the major source of revenue for the Bhutanese Government via domestic and export sales of hydropower. About 90% of total electricity generated from hydropower schemes, which is sold to India remains Bhutan's single major source of revenue. For example, hydropower exports to India accounted for about 45% of the Government revenues in 2000–01 [7]. Thus further development of the energy sector in Bhutan is of crucial importance. As stated before Bhutan's development plans have focused strongly on energy sector development. In the 9th Five-Year Plan, development strategies relevant to the energy

[9] Spin-off effects include roads built for project access, grid electricity, and schools and hospitals built during hydropower scheme development etc.

sector include: creation of an enabling environment for energy sector development—especially for hydropower schemes; rural electrification; strengthening of institutional capacity; automation of generation, transmission and distribution of electricity; determination of tariff systems; preparation of an Energy and Water Resources Master Plan; and further construction of the electricity transmission grid network [3]. Additionally, the revised and updated Power System Master Plan 2003 provides detailed information and management directives on the hydrology, environment and social aspects of hydropower schemes. A comprehensive Rural Electrification Master Plan and investment study is being formulated for the 20 Dzongkhags [3]. This master plan is expected to serve as the road map to meet the Bhutanese Millennium Development Goal of providing access to clean energy services to 50% of the population by 2015; and preparation of plans for achieving the national target of 100% electrification by 2020 [3,21]. An Integrated Energy Management Master Plan is yet to be formulated and will reflect various energy supply strategies based on sectoral needs and forecast energy demand [24].

The Electricity Act 2001 provided the legal framework for restructuring the power supply industry and provided mechanisms for licensing and regulating the operations of the electric power industry and possible participation of the private sector [21,24]. Bhutan has also included energy conservation and efficiency projects in the 9th Five-Year plan. In particular, awareness campaigns regarding standards and labeling programs and pilot projects on lighting using Compact Fluorescent Lamps (CFLs) have been highlighted [38].

There is no specific policy in Bhutan regarding renewables, but the nation has a strong policy focus on hydropower and on forest resources. Overviews of Bhutan's hydropower development policy and forests policies are given below.

4.1. Hydropower development policy

There are no specific policies and laws concerning the use of water resources in Bhutan. However, a national water policy currently is being formulated by the Ministry of Agriculture. This water policy is expected to address policy, legal, and organizational framework aspects for the fair sharing of water resources, and for effective participation, partnerships, and cooperation among stakeholders [39].

Recognizing the importance of hydropower in nation's development, the Government set goals for the hydropower sector in the 9th Five Year Plan. These include: strengthening the economic self-reliance of the nation by further realizing electricity generation capacity from hydropower schemes; and providing adequate, safe and reliable electricity through sustainable and environmentally friendly development of electricity from hydropower [3]. In order to safeguard the environmental consequences of hydropower schemes, the Environmental Assessment Guidelines for hydropower schemes were published by the National Environment Commission (NEC) in 1999 [40]. Also several Environmental Codes of Best Practice (ECOP) have been produced to support the environment assessment guidelines [40].

4.2. Forest policy

Forests as source of fuel wood have been managed and conserved under the auspices of several pieces of legislation in Bhutan. As part of the strong national focus on natural resource conservation, Bhutan is committed to maintain a minimum of 60% forest cover for all time as

reflected in its forest legislation [26]. Forests acts and policies include: *Thrimzhung Chenmo* 1959 (Supreme Law of Bhutan 1959); Bhutan Forest Act 1969; National Forest Policy 1974; Land Act 1979; Royal Decree on Social Forestry 1979; Social Forestry Rules 1990; Forest Policy of Bhutan 1991; and Bhutan Forest and Nature Conservation Act 1995 [29,41]. The Forest Policy of Bhutan 1991 was framed to ensure that forest resources are used according to sustainable principles. The Bhutan Forest and Nature Conservation Act 1995 is a very important piece of legislation in that it provides a strong legal basis for all *social forestry*[10] related activities. This Act also calls for strategies for biodiversity conservation to be built upon two main concepts: conservation values lying in the cumulative effect of species diversity; and that natural resources must be used to meet the collective needs of the Bhutanese people [26]. The Social Forestry Program 1979 was launched by Royal Decree of the King with the aim of promoting local people's participation in the management of forest resources and to reduce pressure on *traditional* forest use [26]. Individuals or communities traditionally used forests in the form of *sokshing*—a forest on which individuals or communities exercised rights to forest resources for the purposes of fuel wood or non-timber products [29,42]. However, in order to provide for formal community participation in conservation and forestry activities, the establishment of the *Dzongkhag Yargay Tshogdu* 2002 (DYT) (District Development Committee) and the *Geog Yargay Tshogchhung* 2002 (GYT) (Block Development Committee) was implemented [29].

4.3. Energy institutions

Before restructure of the institutional settings of the Bhutanese energy sector in 2002, the Department of Power (DoP) within the Ministry of Trade and Industry (MTI) was the sole authority for energy sector development. Restructuring of the energy sector resulted in the formation of the Department of Energy (DoE), the Bhutan Electricity Authority (BEA), and the Bhutan Power Corporation (BPC) [24]. The DoE is the main institution responsible for planning and programming of electricity supply in Bhutan and is situated within the MTI. The DoE consists of four divisions: the Planning and Coordination Division (PCD); the Hydromet Services Division (HMSD); the Renewable Energy Division; and the BEA. The BEA is responsible for regulatory functions related to energy sector issues, development of standards and codes, formulation and approval of tariffs, and their regulation. The BEA is also responsible for implementation of the Electricity Act 2001. At the national level, the BPC is responsible for transmission, distribution and utility functions of the electricity sector. At the Dzongkhag (districts) level, the Electricity Supply Divisions (ESDs) under BPC are responsible for the maintenance of the installation and the distribution of electricity. The BPC is also responsible for implementation of mini/micro hydropower schemes and rural electrification programs through Government and donor-driven activities. The large-scale hydropower schemes at Chhukha, Tala, Kurichhu, and Basochhu have been established as autonomous and independent generating companies under the Companies Act 2000. The Bhutan Power Trading Corporation

[10]In Bhutan social forestry activities include: Community Forestry (CF)—management of local forest activities on Government land, including community lands, by groups of traditional users; Private Forestry (PF)—promotion of tree planting and forest or woodlot activities by individuals on private lands as well as creation of private nurseries and seedling distribution; and the School Social Forestry Program—which involves focusing on education and developing awareness among students about forests (Ura and Kinga, 2004).

(BPTC), a separate company apart from the generating companies, is responsible for power trading and for control of power import and export.

Several other institutions are also associated with energy sector. These include: the Department of Trade within MTI which oversees import and sale of fossil fuels; the Ministry of Agriculture, with regard to the supply of fuel wood through issue of permits; the Department of Forestry Services with its functional division, the Forest Resources Development Division, which prepares the forest management plans and also constitutes the authorizing and controlling body for all *roundwood* extraction and sale in Bhutan [43]; the National Environmental Commission (NEC) which carries out Environment Impact Assessment (EIA) for large hydropower schemes; and the Ministry of Finance which oversees the financial issues of the energy sector.

5. Addressing environmental protection and climate change

The RGB has made rapid strides in recent years in shaping its national policy and legal frameworks in addressing national environment and international climate change issues. Bhutan's local environmental protection framework is sound in its scope and deeply rooted in the *rich traditions* of Bhutanese people. This is attributed to the far-sighted visionary leadership of the King of Bhutan [44].

5.1. Environmental policy

Bhutan's existing environmental strategies focus on the conservation of natural resources including forests and water resources and the protection of wildlife and their habitats. The National Environment Strategy (NES) is the main policy directive for the environment sector (including hydropower schemes) [44]. As well as the Forestry Acts, more recent legislation with regard to environmental protection covers the industrial and mining sectors and environment assessment. Those included are: the Mines and Management Act 1995; the Environmental Assessment Act 2000 [2]; and the Regulation for the Environmental Clearance of Projects [40]. Bhutan also uses the *polluter pays* principle to deter the emissions of environmental pollutants by penalizing offenders [2]. However, there appears to be a need for an umbrella policy framework to facilitate a holistic approach to better address environmental issues. In order to meet this, work on a National Environmental Action Plan (NEPA) is currently underway and it is expected to be enacted by 2007, the end of 9th Five-Year Plan [44]. The NEPA will provide Bhutan with a combination of *regulatory mechanisms* and *fiscal incentives* to encourage public and private sector economic development without compromising the natural resource base. The NEPA will also guide the implementation of the NES [44]. Moreover, Bhutan's rich natural resources have been said to have the potential allow for implementation of a number of innovative mechanisms for financing sustainability [2]. Examples of such potential mechanisms include: bioprospecting[11]; *debt-for-nature* swaps; carbon sequestration; and promotion of environmentally certified products [2].

[11]Bioprospecting is the collecting of biological samples and indigenous knowledge to assist in discovering new genetic or biochemical resources. Under the United Nations Convention of Biological Diversity (CBD) 1992 bioprospecting is regulated through the 'Access and Benefit Sharing Agreement' based on 'prior informed consent' and 'equitable sharing of benefits'.

5.2. Environmental institutions

The NEC coordinates Bhutan's national sustainable development strategy and environmental activities [45]. The NEC also monitors the environmental impact issues associated with the nation's various development schemes [45]. The NEC Secretariat acts as an independent organization under the overall guidance of the NEC [45]. The organizational structure of the NEC Secretariat is shown in Fig. 2.

The long-term objectives of the NEC include formulation and implementation of policies, plans and actions for the sustainability of Bhutan's natural resources. The NEC Secretariat is also responsible for implementing several projects, for example: Environment Sector Program Support; the Bhutan National Greenhouse Gas Project; Capacity 21 Project; National Capacity Self-Assessment Project; National Adaptation Program of Action; and Environmental Sectoral Guidelines [45]. The NEC Secretariat also oversees Bhutan's obligations to numerous regional and global environmental conventions and treaties [45]. The NEC is comprised of the following members: the Minister for Agriculture (Chairman); the Minister for Trade and Industries; Deputy Minister for Communication; Deputy Minister for the NEC; the Secretary of the Planning Commission; the Surveyor General; and the Director General of the Department of Education [45].

However, in line with the decentralization policy of the RGoB, the District Environment Committees (DECs) in the Dzongkhag*s* (districts) will enforce the Environmental Assessment Act 2000 and will also expedite the environmental clearance process [44]. The terms of reference for DECs and the relationship between them and the NEC are yet to be finalized.

To ensure an effective environmental conservation program, Bhutan has initiated a unique *environmental trust fund*, the Bhutan Trust Fund for Environment Conservation (BTFEC). The BTFEC was established in 1991 as a sustainable, domestic funding source for Bhutan's environmental programs [46]. However, challenges exist in terms of addressing new and emerging environmental issues under the BTFEC. These include: lack of a framework to strategically address ecological stress factors that rapidly and negatively impact human needs; and the impacts of geo-politics and globalization [46].

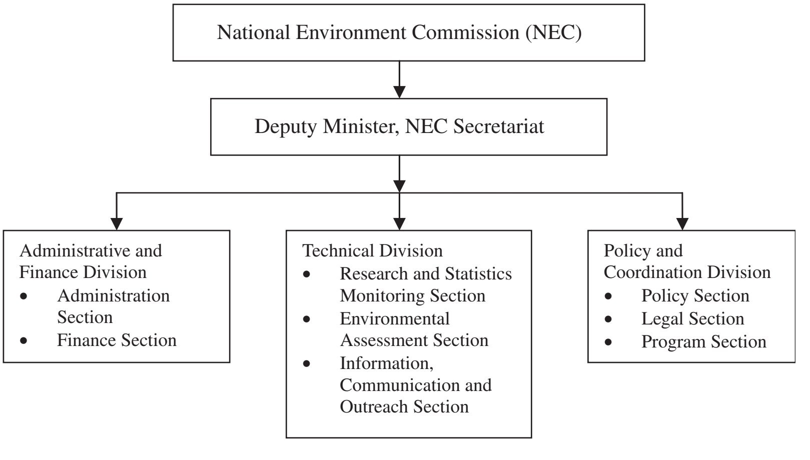


Fig. 2. Organization structure of the NEC Secretariat. *Source*: Adapted from NEC, 2005b.

In order to cooperate on international climate change issues, Bhutan signed the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and ratified the agreement in 1995. To facilitate UNFCCC responsibilities, the NEC was designated to host the National Climate Change Committee and NEC Secretariat as the focal institution for the UNFCCC. Bhutan submitted its initial national communication and first national greenhouse gas (GHG) inventory in 2000 and acceded to the Kyoto Protocol in 2002 [47]. Also, the NEC acts as a Designated Operational Entity (DNA) to the UNFCCC and is responsible for approval of GHG emission reduction projects (including renewable energy and energy conservation projects) under the Clean Development Mechanism (CDM) of the Kyoto Protocol. With the aim of furthering the objectives of environmental conservation, Bhutan also works closely with regional environmental bodies such as the South Asia Cooperation Environment Program (SACEP) on regional environment and air pollution issues [44].

6. Demonstration projects

Bhutan's strong commitment to protect the environment and to follow *the Middle Path* of development has resulted in the implementation of several demonstration projects aimed towards better environment and development outcomes. Among others, there have been a number of capacity building and demonstration projects on sustainable energy (renewables and energy efficiency). These projects were initiated by Bhutanese Government institutions via support from national and external aid. For example, two sustainable energy projects, Improved Community Cooking Stoves—An Alternative to Mitigate Fuel Wood Pressure in Trashigang, and the Biomass Fuel Efficiency Project were funded under the Small Grants Program (SGP) of the UNDP [19]. However, these projects registered a mix of success. The Biomass Fuel Efficiency Project was able to systematically integrate local capacity building activities during its implementation, which ensured its success beyond project duration, whereas capacity building activities were not well targeted in the case of the Improved Community Cooking Stove project [19]. Other projects under UNDP/SGP scheme included Promoting Alternative Energy through Use of Solar Water Heater Systems and Biomass Wastes Briquetting [30]. Both projects showed mixed results due to several barriers [30]. In the case of the solar water heater project: beneficiaries of the project were passive recipients; there were language barriers due to a lack of *Dzongkha*[12] language skill of local village people or beneficiaries; and the intervention was of a highly technical nature [30]. Potential benefits and the efficacy of the Biomass Wastes Briquetting Project were constrained as: the existing briquetting unit was reported as too small[13]; the briquetting unit frequently stalled due to mechanical problems; and sawdust required repeated drying due to its high moisture content as a result of high precipitation [30].

In 2003, a further Solar Energy Project in Bhutan was initiated by the Solar Electric Light Fund (SELF) with support from the RGB, the Bhutanese Royal Society for the

[12] *Dzongkha* is the modern Bhutanese vernacular language derived from Old Tibetan through many centuries of separate evolution on Bhutanese soil. Many Bhutanese live outside urban areas (especially in remote areas) usually speak in local dialects not the national language.

[13] The project proposal projected annual production capacity at 2800 t/year. Actual production capacity, however, is likely to be much less due to recurrent mechanical problems and the necessity of repeated drying of sawdust.

Protection of Nature, the Tshungmed Solar Inc., the Bhutan Development Finance Corporation, and the Bhutan Trust Fund [48]. The project aimed to bring small solar home systems to about 200 families in the Phobjikha Valley [48]. This project had two critical components, which gave the project long-term success. First, solar home systems were not donated to the families free of charge; instead, SELF provided seed capital and a mechanism for families to secure micro loans for purchase of their solar home system. Second, SELF, along with its local partners, Tshungmed Solar and SELCO India, trained local men and women in solar technology, installation, and maintenance, thus ensuring that the project could be maintained over the longer term after the project implementation period [48]. Arguably, although the SELF project was more effective, a more comprehensive strategy was needed to make all these projects useful in the long-term and economically viable.

6.1. The e7 micro-hydropower CDM scheme

Bhutan recently has had experience in commissioning a first small-scale CDM[14] project under the Kyoto Protocol. The overall objectives of the project include: to demonstrate a first project under the CDM based on micro-hydropower; to construct a micro-hydropower scheme in the remote village, Chendebji, to support rural electrification and realize the synergistic benefits to rural communities; and to contribute to the CDM rule-making process by addressing the challenges and measures undertaken from project initiation to implementation [49]. The Chendebji 70 kW micro-hydropower project is financed by the e7 Fund[15] and is currently being implemented by the DoE on behalf of the RGB. The e7 micro-hydropower scheme was approved by the NEC as Designated National Authority (DNA) and the NEC Secretariat issued the Environmental Clearance for the project. Further the RGB approved the proposal for 50% of sharing the Certified Emissions Reduction (CER)[16] from the project between the RGB and the e7 Fund. The development history of the project and its technical features are given in Boxes 1 and 2, respectively.

[14]In accordance with decision 17/CP.7 simplified modalities and procedures have been developed for the following types of small-scale CDM project activities:

(i) Renewable energy project activities with a maximum output capacity equivalent to up to 15 MW (or an appropriate equivalent);
(ii) Energy efficiency improvement project activities which reduce energy consumption, on the supply and/or demand side, by up to the equivalent of 15 GW/h per year;
(iii) Other project activities that both reduce anthropogenic emissions by sources and directly emit less than 15 Kt of carbon dioxide equivalent annually (www.unfccc.int/cdm accessed on January 18, 2006).

[15]e7 is an international group comprised of largest electrical utilities from G7 countries. The e7 mission is to play an active role in global electricity use and to promote sustainable development www.e7.org accessed on January 18, 2006.

[16]A certified emission reduction or CER is a unit issued pursuant to Article 12 and requirements there under, as well as the relevant provisions in the CDM modalities and procedures, and is equal to 1 t of carbon dioxide equivalent, calculated using global warming potentials defined by decision 2/CP.3 or as subsequently revised in accordance with Article 5 of the Kyoto Protocol (www.unfccc.int/cdm accessed on January 18, 2006).

Box 1
Development history of the e7 micro-hydropower scheme

Nov 2001:	Pre-feasibility study conducted for a micro-hydropower scheme
Nov 2002:	Feasibility study conducted; the e7 Fund and the Royal Government of Bhutan concluded a MoU
July 2003:	The Government of Japan, as Annex 1 Parties approved the project as a CDM
Feb 2004:	The Royal Government of Bhutan approved the project as a CDM project as host country (Non Annex 1 Party)
May 2005:	Project was registered as a CDM project by UNFCCC
Aug 2005:	Project began generating electricity

Source: Adapted from Ikoma and Tshering, 2005.

Box 2
The technical features of the e7 micro-hydropower scheme

Head:	50 m
Maximum water discharge:	0.2 m^3/s
Plant output:	70 kW
Annual power generation:	582.54 MWh
Turbine type:	Cross-flow
Inlet valve:	Sluice valve
Generator type:	Horizontal shaft; revolving-field type; three-phase synchronous generator
Rated voltage:	400 V
Rated power factor:	0.8 lagging
Frequency:	50 Hz
Total reduction in CO_2 emission:	524 t-CO_2/year for 21 years
Estimated cost of the project:	US$280,000 $\pm$ 25%
CERs:	Price is yet to be determined; 50:50 share of CERs between the RGB and the e7 Fund
Additional project features:	Five institutional buildings; transmission/distribution lines

Source: Adapted from e7, 2005.

The e7 is responsible for the construction of the hydropower scheme. However, the DoE of RGB will be the owner of the project and the local community, the Trongsa District Administration and Chendebji Village, will be responsible for the operation and maintenance as well as management of the power plant. The monitoring of the project will be done under the direct technical guidance of the DoE and the e7 will conduct the necessary training on operation and monitoring of the power plant [50].

The e7 Bhutan micro hydropower CDM project is currently at its initial stage of operation. Thus it is difficult to assess at this very early stage the synergistic benefits and contribution to sustainable development in Chendbji Village. However, a number of lessons have been learnt and considerable knowledge appears to have been gained from the e7 by the Bhutanese Government via local learning about the administration and implementation of the CDM project. Useful aspects have included: the importance of stakeholders' engagement—especially the local communities; identifying a sustainability framework and indicators; both Annex 1 and Non-Annex 1 Parties have needed to understand the CDM process and its relevance to national laws and plans; a small-scale CDM project is more cost-effective; and the capacity building for the DNA, and other stakeholders in the CDM project cycle [49].

7. Remaining challenges and future strategies

Bhutan has shown a steep development trend in the last four decades. However, Bhutan faces major development challenges due to its setting as a landlocked country with a small economy and thus a small domestic energy market. This also results in higher costs for social services and the development of infrastructure [6,35]. In addition, a lack of skilled labor and a lack of technical expertise also have been experienced. Despite the fact of tremendous accomplishments registered, particularly in the last two decades of development, Bhutanese institutions are still new and fragile, and substantial challenges remain due to its high population growth and *the Middle Path* development strategy [5]. In fact, striking a balance between *tradition* and *modernity* will be the greatest future challenge of the nation. This is because liberalization emanating from various levels of integration although arguably beneficial for Bhutan is also gradually posing several challenges to the economy and the society. The perseverance of culture and tradition is one such challenge [16].

Moreover, the major economic risk of Bhutan is its current high dependence on a one-country-one-commodity framework via hydropower which, tends to make Bhutan vulnerable to the pressures of development from across its southern border [51]. This eventually may damage the non-power trade sectors e.g. manufacturing and mining, and also non-trade sectors e.g. services and construction [52].

Decentralization of both institutional settings and central Government control of administration should lead to effective public participation in decision-making and take greater local responsibility for necessary infrastructure and services. Also the need for an umbrella policy framework has been recognized as necessary to facilitate a holistic approach to address the nation's environmental issues. Despite the fact of early success of selected development projects, specifically sustainable energy projects, a more comprehensive strategy is necessary to make these projects tangible and economically viable. Importantly, Bhutan's strong, Government-led agenda (rather than a donor-driven one) provides a secure sense of national cohesion on policy, which has been acknowledged by

donors as an example of best practice [4]. However, the significance and extent of impact of the Middle Path of development is yet to be revealed in the long-term especially as the King of Bhutan will officially hand over power to the people in 2008 [53,54].

8. Concluding remarks

The historical, cultural and physical characteristics of Bhutan have contributed to development of a unique Bhutanese national identity. However, external pressures have led the nation to open its doors, and enter the global game as a *late player*. Bhutan has registered considerable development achievements with some sustainability focus during the past two decades and further institutionalization of the Middle Path of development approach will be important for continuing these development trends. Further, formulation of short- and long-term Middle Path strategies for development should result in enhancement of the nation's sustainable development trends to date. Identifying all the possibilities for renewable resource usage for example, with forest-based products, use of low priced electricity for manufacturing goods, and use of water resources in a more sustainable way could reduce the current Bhutanese vulnerability of its one-commodity-one-country dependence. Also, new financing mechanisms for example, CDM, could enhance sustainability in different sectors.

In the coming years, approaches to capacity building and the scope for implementation of new projects and financing mechanisms will need careful evaluation with regard to their appropriateness for implementation in line with the Middle Path of development. The distinct Bhutanese path of development is not necessarily aligned with the dominant western approach. It is hoped that Bhutan will deal successfully with external influences and will be guided by the experience from best practice to date such as with implementation of its sustainable energy projects.

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